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13. ABSTRACT (Maximum 200 words)
This program has focused upon two areas: 1) development of computer-aided design models for RF/optical links and 2) development of low-cost, wide bandwidth opto-electronic intergrated circuits. We have used existing CAD tools to model an optical subcarrier multiplexed (OSCM) communication network to study the effects of RF component integration on system performance and network scalability. The simulation approach presented here enables us to study the effect of RF component integration and determine critical design criteria in order to enhance system performance. Integration of RF/Optical interfaces will allow deeper penetration of RF and lightwave component technology into optical packet networks. We have begun to integrate InP based electronic and optoelectornic devices (using substrate removal techniques) with commercially available GaAs circuitry for emerging wireless applications between 1 and 100 GHz. Ou r effort includes a) Optimization of substrate removal and bonding for InP material devices to preserve DC and RF characteristics and b) Suitable host substrate passivation for optimization of the high speed device after bonding. For the upcoming year, we plan to design and fabricate OEICs based upon GaAs MMICs to study: a) impact upon OSCM networks and b) provide low-cost approaches for 10GB/s links.

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ABSTRACT

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Final Report

(1) Title of Project: YIP: Optoelectronic Computer-Aided Design Models

(2) Contract Number: Proposal Number (P-34576-EL-YIP), Grant Number (DAAH04-95-1-0397)

(3) Period Covered by Report: 1/1/95 to 8/31/98

(4) Institution: School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332-0250.

(5) Principal Investigator: Professor Joy Laskar

(6) Major Accomplishments: (see attached publications)

Development of low-cost, wide bandwidth optoelectronic integrated circuits

We have begun investigating integration of InP based electronic and optoelectronic devices (using substrate removal techniques) with available GaAs and Si circuitry for emerging optical and wireless applications between 1 and 100 GHz. Our efforts include (a) Development of substrate removal and bonding for InP material devices to preserve DC and RF characteristics, (b) developing long-wavelength OEICs using GaAs MMIC technology, (c) studying surface and interface state densities between bonded surfaces. These results have been reported in the IEEE Electron Device Letters, Electronics Materials Conference, and the IEEE Microwave Theory and Techniques Symposia. In addition, we have demonstrated the first integration of high frequency, three terminal InP device performance on InP substrates. This result has been reported in the EE Times magazine.

Development of computer aided design models for RF/optical links

Major accomplishments have been achieved by applying microwave CAD tools to optical subcarrier multiplexed (OSCM) communication networks to study the effects of RF component integration on system performance and network scalability. The simulation approach presented here enables us to study the effect of RF component integration and determine critical design criteria in order to enhance system performance. Integration of RF/Optical interfaces will allow deeper penetration of RF and lightwave component technology into optical packet networks. We have carried out several design runs to study the impact of MMICs upon optical/microwave communication systems. Several MMIC components have been fabricated for use in an OSCM link and were realized using the Triquint Semiconductor HA2 and QED/A GaAs Enhancement/Depletion MESFET processes.

A MMIC mixer design for control-channel transmission has been realized and a dual-gate topology is employed for better isolation between th local oscillator (LO) and intermediate frequency (IF). Oscillators for subcarrier signal generation have also been realized. A common-gate single-FET configuration is used for simplicity and compact design. These devices generate 2.5-, 3.5-, 4.5-, and 9-GHz carriers. We are currently designing and processing more MMIC components to improve OSCM link performance.

These results have been reported at the IEEE Microwave Theory and Techniques Symposia and has been published in a special issue of the IEEE Transactions on Microwave Theory and Techniques

Fused Wafer Study (Initial Work in Progress and Strong Candidate for follow on ARO Funding)

Currently, static I-V measurements have been made on GaAs-GaAs and GaAs-GaP fused wafers, with rotational misalignment of 0, 10, and 90 degrees. The data show an overall trend toward reduced current density as a function of relative wafer misorientation, although wide variation from sample to sample is noted. In addition, some rectification near zero bias is noted in some samples.

Static and high frequency C-V measurements can be used to detect the interface trap density. The depletion capacitance will be observed on both high and low frequency measurements. Since the trap lifetimes will typically be relatively long, the interface capacitance due to ionized traps will be present in the low frequency C-V measurements, but will be absent from the high frequency measurements. Deep level transient spectroscopy (DLTS) uses accurate transient C-V measurements at multiple temperatures to determine multiple trap energy levels, emission cross-section, and density of states.

Optical experiments will help characterize the bonded interfaces as well. The fundamental C-V measurements can be conducted when illuminated with a monochromatic infrared source, pumping trapped electrons to the conduction band, thereby altering the trapped surface state charge. By switching the light source off, the trap lifetime can be measured. [I believe this is referred to as photocapacitance quenching.] Photoluminescence spectroscopy supplements DLTS in determining the trap energy levels as well as trap density.

These data will be of great use in modelling the current-voltage characteristics, as it is determined primarily by the wafer misorientation for significant angles, even in bonded heterojunctions. The well defined distribution of the defects along the dislocation lines in the interface yields electrical characteristics distinct from randomly distributed defects. The nature of the defects and control of their density may be well suited to high speed electronic devices.

(7) Technology Transfer Initiatives:

This project is closely coordinated with industry partners. The following is a list of current and ongoing developments:

- We have been collaborating with Triquint Semiconductor to develop MMIC chip sets for both long wavelength OEICs and microwave/optical communication links. We presently have been submitting two MMIC designs per quarter.

- Several MMIC Design Models have developed and inserted into the Communication Design Suite available from HP.

- We have been collaborating with Raytheon/Texas Instruments to study the impact of thin film integration of high frequency InP components. These results have been reported in EE Times and represent the first example of direct thin-film integration of InP components onto Si substrates.

- We have begun a collaboration with Hewlett-Packard San Jose optoelectronics group to study the electrical characteristics of bonded interfaces. This has the potential for significant impact upon optoelectronic development.

(8) Conference/Workshops:

(1) S. Han, R. Gaudino, M. Shell, J. Laskar and D. Blumenthal, "Optimization of RF (MMIC)/Optical Subcarrier Mulitplexed Communications System," Presented at 1997 IEEE Microwave Theory and Techniques Symposia, Denver, June 1997.

(2) C. Chun, N. Evers, J. Laskar and N. Jokerst, "InP HBT on Si Substrates with Integral Passive Components: A Wafer Scale Package," Presented at 1997 IEEE Microwave Theory and Techniques Symposia, Denver, June 1997.

(3) C. Chun, O. Venier, E. Moon, J. Laskar, N. Joerst, M. Brooke, and H. Ki, "Integrated 1.55μm Receivers using GaAs MMICs and Thin Film InP Detectors," To Be Presented at 1998 RFIC Symposium, Baltimore, June 1998.

(9) Papers, Honors, Etc.

Papers

[1] N. Evers, J. Laskar, N. M. Jokerst, T. S. Moise, and Y.-C. Kao, "DC and High Frequency Performance of Thin Film InP-based Tunneling Hot Electron Transfer Amplifiers," *Applied Physics Letters,* vol. 70, pp. 2452-2454, May 1997.

[2] D. J. Blumenthal, J. Laskar, R. Gaudino, S. Han, M. Shell, and M. D. Vaughn, "High-Performance Baseband Data and Subcarrier-Multiplexed Control Links in Fiber-Optic Networks and the Impact of MMIC Photonic/Microwave Interfaces," *IEEE Trans. on Microwave Theory and Technology,.* vol. 45, pp. 1443-1452, August 1997.

Awards and Honors

[1] 1996 National Science Foundation CAREER Award Recipient (Formerly Presidential Young Investigator Program).
[2] IEEE MTT-S Linear Device Modeling Session Chairman (1996).
[3] IEEE MTT-S Non-Linear and Coupling in Packages Session Chairman (1997).
[4] Co-Organizer Panel Session for IEEE MTT-S Optical/Microwave Modules (1997).
[5] Promoted to Associate Professor with Tenure at Georgia Tech, 1998.